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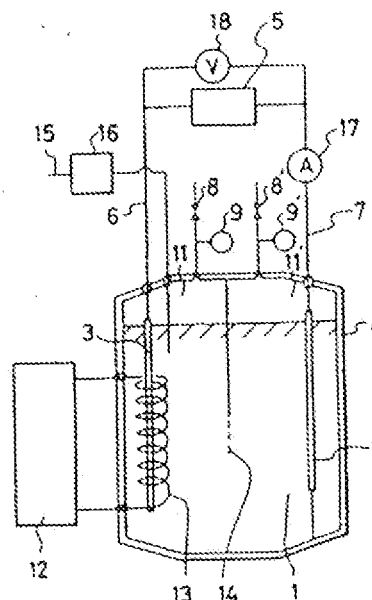
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06.02.91 Bulletin 91/06(1) Applicant: SEMICONDUCTOR ENERGY  
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(4) Electrochemical nuclear fusion method.

(5) A method of producing an electrochemical nuclear fusion reaction comprises the steps of introducing in a reaction vessel a solution containing heavy water, so that a pair of electrodes disposed in the reaction vessel are immersed in the solution, and applying pulsed electrical energy across the electrodes to produce an electrochemical reaction for a nuclear fusion reaction

FIG. 1



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# EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
P	NUCLEAR ENGINEERING, vol. 34, no. 418, May 1989 "THE do-it-yourself fusion reactor" page 10	
Y	* Page 10 *	1,7
A	* Page 10 *	2-6, 8-10
Y	US - A - 4 650 630 (BOYER) * Fig. 1-3; abstract *	1,7
A	* Fig. 1-3; abstract; claims *	2-5
P	WO - A1 - 90/00 301 (DIJKHUIS) * Page 14, table 5; abstract; claims *	
A		1-9
		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
		G 21 B 1/00 G 21 D 7/00
The present search report has been drawn up for all claims		
Place of search	Date of completion of the search	Examiner
VIENNA	30-11-1990	KRAL
CATEGORY OF CITED DOCUMENTS		
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : oral-written disclosure P : intermediate document I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document		

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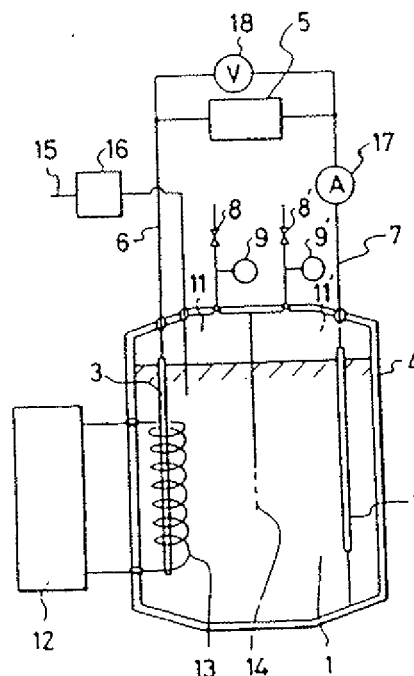
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(54) Electrochemical nuclear fusion method.

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FIG. 1



## ELECTROCHEMICAL NUCLEAR FUSION METHOD

### BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention relates to a method of attaining improved reliability in the implementation of a nuclear fusion reaction, and specifically to a method of controlling the extent of that nuclear fusion reaction by using a pulsed voltage for DC current.

#### Description of the Prior Art

A nuclear fusion reaction by electrochemical process, which is referred to as cold nuclear fusion, has been attained and reported by S.E. Jones et al. The paper is entitled "Observation of Cold Nuclear Fusion in Condensed Matter" and was authored by S.E. Jones, E.P. Palmer, J.B. Crirr, D.L. Decker, G.L. Jensen, J.M. Thorne, S.F. Taylor, (all of Brigham Young University), and J. Rafelski (University of Arizona).

In this reaction, a pair of electrodes comprising a palladium or titanium cathode and a gold or platinum anode are inserted into a solution containing heavy water, and a DC voltage is applied across these electrodes. In addition, the electrochemical nuclear fusion reaction is carried out at an atmospheric pressure.

Because of the fact that this reaction is carried out at the atmospheric pressure, there is little possibility that deuterium (D) atoms combine with other deuterium atoms to produce the nuclear fusion.

In addition, the reaction tends to occur in one localized section of the electrodes, and then the nuclear reaction would occur in that localized section from the rise in temperature at that point.

Also, palladium which is used as a catalyst for combining the deuterium atoms is easily poisoned to form a poisoned film, and it is difficult to break down the poisoned film to produce a uniform nuclear fusion. For this reason, there is a high degree of variation and a lack of reproducibility in the nuclear fusion reaction. In addition, because of the occurrence of electrochemical side reactions which takes place simultaneously with the nuclear fusion, most of the products of the reaction decompose and the deuterium is eventually released into the atmosphere. As a result, the amount of deuterium actually used in the nuclear fusion reaction is considerably less than expected. Therefore, a method of reliably controlling the nuclear fusion reaction with a high probability of nuclear fusion occurring is

further required.

### SUMMARY OF THE INVENTION

An object of the present invention is to provide, with due consideration to the drawbacks of such conventional methods, a method by which it is possible to reliably implement an electrochemical nuclear fusion reaction by maintaining the reaction environment under high pressure.

A further object of the present invention is to provide a method by which it is possible to control the extent of the nuclear fusion reaction by applying a pulsed DC voltage to the reaction system and keeping the voltage enough high to produce the nuclear fusion reaction.

A further object of the present invention is to provide a method by which it is possible to control the extent of the nuclear fusion reaction by changing the pulse width or duty ratio of the pulsed voltage in the reaction system including a palladium electrode, so that the reaction is uniformly carried on over the palladium electrode.

A further object of the present invention is to provide an apparatus in which it is possible to reliably implement an electrochemical nuclear fusion reaction by applying a pulsed DC voltage to a solution for reaction in the apparatus and keeping the voltage enough high to produce the nuclear fusion reaction.

These objects are achieved in the present invention by the provision of a method wherein the reaction vessel containing a solution for reaction is maintained at a high pressure, and a pulsed DC current is applied to the solution to produce the electrochemical nuclear fusion reaction under control.

In the present invention, the high pressure in the reaction vessel can be produced for reaction by confining in the reaction vessel the deuterium (D<sub>2</sub>) per se produced as a gaseous material in the electrochemical reaction, so that the efficiency of the nuclear fusion reaction is totally increased.

In the present invention, the thermal energy produced in this reaction is transferred into a heat transfer medium which is passing through a heat exchanger in the reaction vessel. By conducting this heat transfer medium from the reaction vessel, it is possible to remove the energy, in particular the thermal energy from the nuclear fusion reaction for use as a simple thermal energy source in industrial applications such as electrical generation, heating, and the like.

### BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features, and advantages of the present invention will become more apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a device for experimental execution of the method of the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a reaction method and an apparatus by which it is possible to implement an electrochemical nuclear fusion reaction under control by applying a pulsed-type DC voltage.

The process in the present invention is carried out in a reaction vessel into which a pair of electrodes are incorporated. Specifically, for example, palladium or titanium is used for the cathode and gold or platinum for the anode of the electrodes in the present invention.

A pressurized reaction vessel is used for the reaction vessel to accommodate a solution which contains heavy water.

A DC voltage in the form of a continuous DC voltage or a pulsed-type DC voltage from a power source is applied between the electrodes.

A pair of heat exchangers are provided to remove the energy of nuclear fusion from the pressurized reaction vessel in order to prevent the excessive increase in temperature within the reaction vessel.

Further, a shield plate is inserted between the electrodes to prevent mixing of deuterium ( $D_2$ ) and oxygen ( $O_2$ ) which are produced through reaction, thus preventing the generation of heat from a further chemical reaction.

The deuterium and oxygen may be used to increase the pressure in the reaction vessel by making the reaction vessel in a hermetic structure.

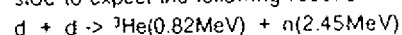
In the process of the present invention, a solution of heavy water ( $D_2O$ ) containing a predetermined metal salt is introduced between the electrodes in the reaction vessel. This metal salt is selected from the group of  $FeSO_4 \cdot 7H_2O$ ,  $NiCl_2 \cdot 6H_2O$ ,  $PdCl_2$ ,  $CaCO_3$ ,  $LiSO_4$ ,  $NaSO_4 \cdot 10H_2O$ ,  $CaH_2(PO_4)_2 \cdot H_2O$ ,  $TiSO_4 \cdot H_2SO_4 \cdot 8H_2O$ , and  $AuCN$ . Specifically, 0.03 to 0.3 gm of the salt, for example, 0.13 gm of the salt is added to 100 gm of the heavy water.

In addition,  $HNO_3$  is added to the solution to adjust the pH of the solution to 3 or lower.

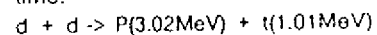
An external voltage, specifically a pulsed DC

voltage, is applied across the electrodes, and atoms of deuterium ( $D$  or  $d$ ) are created at the palladium cathode while oxygen is produced at the anode. A neutron counter is positioned close to the reaction vessel to provide evidence to confirm the occurrence of nuclear fusion.

The neutrons ( $n$ ) are detected on the cathode side to expect the following reaction:



In addition to the reaction above, the following reaction can be expected to occur at the same time:



As a result of nuclear fusion, an increase in temperature of the heavy water solution is observed. The number of neutrons with an energy of 2.5 MeV is not necessarily large, but their existence can be detected with a neutron spectrometer.

When nuclear fusion takes place under pressure the neutrons cause the subsequent nuclear fusion by breeding, which may lead to an atomic explosion. Therefore, to prevent the occurrence of the atomic explosion, the extent of the electrochemical reaction must be controlled. For this reason, an adequately higher voltage than the voltage necessary for the reaction is applied, and the voltage is intermittently applied, in other words, the duration of application of the voltage is pulsed and controlled corresponding to the nuclear fusion reaction condition, whereby the reaction is controlled so as not to exceed the nuclear fusion critical value.

Specifically, the pulsed voltage is applied at 1 to 1000 pulses per minute and the pulse width is also varied from 0.1% to 100%. The 100% pulse width means a continuous state, which is referred to as DC continuous voltage. As a result, in the case where the DC continuous voltage is applied, the existence of nuclear fusion is observed even at as little as 20 V. In the case where a sufficiently high DC pulsed voltage, for example, 30 to 100 V, and especially, for example, at 40 V is applied with a duty ratio of 50% and a frequency of 30 times per minute, it is possible to suppress or control the extent of the nuclear fusion. Here, the term "duty ratio of 50%" means that the voltage is applied for 50% of a single cycle with no voltage applied for the other 50% of the cycle.

Furthermore, the extent of the creation of neutrons and the extent of the temperature rise is seen to increase as the pressure in the reaction vessel increases.

In comparison with the case where the reaction is carried out at atmospheric pressure, the nuclear fusion reaction is obviously accelerated when the reaction at the cathode is implemented under high pressure. The pressurization can be varied over the range from 2.3 atm to 200 atm provided that normal atmospheric pressure is equivalent to one atm.

The reaction can, of course, be implemented at greater pressures, but in such a case there is some danger of an explosion occurring, and it can be assumed that the danger increases with the increase in the efficiency of the reaction.

The present invention will become more clear by the following examples.

#### EXAMPLE 1

Now referring to FIG. 1, which illustrates the nuclear fusion reaction vessel used in the present invention, a pressurized reaction vessel 4 was used for the nuclear fusion reaction vessel, and a solution 1 which essentially consisted of heavy water ( $D_2$ ) and a salt added to the heavy water was enclosed in the pressurized reaction vessel 4.

A pair of electrodes 2, 3 fabricated of gold and palladium respectively were used in the reaction vessel 4. A DC voltage, e.g. of 40V in the form of a pulsed-type DC voltage from a power source 5 was applied between the palladium electrode 3 as the cathode and the gold electrode 2 as the anode with a duty ratio of 50%. Specifically, the voltage is applied for 50% of a single cycle with no voltage applied for the other 50% of the cycle.

A pair of heat exchangers 12, 13 were provided to remove the energy of nuclear fusion from the vessel 4 in order to prevent the increase in temperature within the reaction vessel 4 from proceeding too far. The heat exchanger 13, which was a spiral-type heat exchanger, was positioned adjacent to the palladium electrode (cathode) 3. A shield plate 14 fabricated from lithium glass was inserted between the electrodes 12, 13 to prevent mixing of deuterium ( $D_2$ ) 11 and oxygen ( $O_2$ ) 11' which were produced through reaction, thus preventing the generation of heat from a chemical reaction between the deuterium ( $D_2$ ) 11 and the oxygen ( $O_2$ ) 11'.

When the pressure has become too high, the oxygen 11' is let to go out of the reaction vessel 4.

The catalyst electrode or palladium electrode 3 is placed under a high pressure to absorb the deuterium ( $D_2$ ) gas contained in the heavy water.

The deuterium and oxygen were used to increase the pressure in the reaction vessel. In addition, a pair of safety valves 8, 8' and a pair of pressure gauges 9, 9' were provided for adjustment of the pressure. The DC power source 5 was connected to the electrodes 3, 2 respectively through a pair of leads 6, 7. The leads 6, 7 were electrically isolated from the reaction vessel 4.

In this example, the reaction vessel 4 produced for an experiment purpose was sized so that at most about 20 cc of reactants could be charged into the reaction vessel 4. However, if this nuclear

fusion reaction are to be used for industrial purposes, the size of the reaction vessel can be increased, so that a charge of 10 to  $10^4$  times this amount may be accommodated, or it would be possible to use a plurality of such small reaction vessels juxtaposed.

In addition, a supplementary supply of the solution 1 may be continuously charged into the reaction vessel 4 from an external source 15 of solution through a pressure charging system 16.

In this experiment example, 10 cc of heavy water ( $D_2O$ ) containing a salt were charged into the high pressure reaction vessel 4. The salt used was  $NiCl_2 \cdot 6H_2O$ , which was added in the ratio of 0.13 vol% of the heavy water. The pH of the solution was adjusted to 2.8 by the addition of nitric acid.

In the experiment, a continuous DC voltage was initially applied between the palladium electrode as the cathode and the gold electrode as the anode and deuterium ( $D_2$ ) was produced at the cathode and neutrons were detected by a neutron counter (omitted from the drawing). At this time, when the reaction was occurring at atmospheric pressure, a count of only about 4, in another words 3 to 10, was observed at an energy of 2.5 MeV, but, for example, when the duty ratio was increased to 75% in a manner that the voltage was applied for the time period of 45 seconds with no voltage for the 15 seconds in a single minute, the count number increased by about 6 times.

In addition, water was circulated through the heat exchangers 12, 13, and heat generation in this circulated water was clearly observed.

The deuterium 11 and oxygen 11' generated from this nuclear fusion reaction with the pulsed voltage application were not released to atmosphere but were confined within the high-pressure reaction vessel 4 to increase the pressure therein. A predetermined pressure can desirably be maintained by ejecting through the safety valves any gaseous materials which were not required. In this example, oxygen gas was ejected as unnecessary gaseous material. This release of oxygen was also made to prevent a secondary electrochemical heat generation reaction between deuterium and oxygen in the pressurized state to prevent a sudden generation of heat.

It was found in Example 1 that deuterium adhered to the cathode of palladium electrode 3 during the reaction when the voltage applied at the power source 5 was increased 50V as detected at the voltmeter 18. However, when the deuterium was adhering to the palladium electrode 3, the result was a trend toward diminishment of the area of the palladium electrode 3. This was observed experimentally. Therefore, the reaction could not be kept uniform over the total electrode area. Because of this, the breeding by neutrons generated

from parts of the reaction concentrated in localized areas caused more positive nuclear fusion reaction in the areas.

It was also found in Example 1 that when the reaction was carried on for one hour, surface poisoning occurred in the palladium electrode 3 and thereafter an adequate nuclear fusion reaction could not be produced at the same voltage.

In this example, it was also found important to remove any catalyst poison to prevent the catalytic reaction on the palladium side.

## EXAMPLE 2

The embodiment in Example 2 was carried out in the same manner as Example 1, except that the voltage applied at the power source 5 was increased to 60 V as detected at the voltmeter 18. This caused the electric current through the line 7 to increase as detected at the ammeter 17.

In addition, taking into consideration of the localized reaction as mentioned above in Example 1 when the voltage was applied high, an alternative experimental procedure was adopted, that is, a voltage sufficient to produce the nuclear fusion reaction was applied, and a pulse width duty ratio of 100% (DC voltage) was not used, but rather the duty ratio was varied in a range less than 100%, so that a nuclear fusion reaction occurred intermittently. The term "pulse width duty ratio" means the period of time in ratio through which voltage is applied during one cycle.

Therefore, the reaction was produced uniformly over the entire cathode of palladium electrode 3 and it was also possible to control the extent of the nuclear fusion reaction, inasmuch as the breeding was not caused by subsequent neutrons. Therefore it was expected that the generation of nuclear fusion could desirably be controlled. Specifically, in Example 2, a DC voltage of 60 V was applied and the duty ratio was varied from 10% to 90%. For example, a 50% duty ratio was attained wherein 50 V was applied between the two electrodes during 50% of the time period over one minute.

By varying the duty ratio from 10% to 90% to intermittently apply a higher voltage, the number of neutrons was also increased in proportion. Consequently, in Example 2, it was possible even after 10 hours to obtain a satisfactory nuclear fusion reaction at the same voltage as initially applied, and the temperature in the circulated water correspondingly rose from room temperature to 40°C. It was recognized that the palladium electrode was prevented from being poisoned, and any poisoned film was substantially not produced.

By means of the present invention, it has become possible to continuously carry on an artificial

nuclear fusion reaction, controlling the extent of the reaction, which had been deemed impossible to perform in the past. For this reason, the present invention has extremely large industrial implications.

The efficiency of the heat exchangers to remove energy from the reaction vessel can further be increased, so that removal as boiling water at 100°C to 130°C is possible by improving and making scale-up the nuclear fusion reaction device. These are also modifications of the present invention.

In addition, other modifications are possible within the scope of the present invention.

## Claims

1. A method of producing an electrochemical nuclear fusion reaction comprising the steps of: providing a reaction vessel,

providing the reaction vessel with a pair of electrodes disposed therein,

introducing in the reaction vessel a solution containing heavy water, so that the pair of electrodes are immersed in the solution; and

applying pulsed electrical energy across the electrodes to produce an electrochemical reaction for a nuclear fusion reaction.

2. The method of claim 1, wherein the pulsed electrical energy is applied with a duty ratio of 10% to 90% and at a rate of 1 to 1000 cycles per minute.

3. The method of Claim 2, wherein the electrochemical reaction is produced in a hermetically sealed space; and the high pressure is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction is carried out under the high pressure.

4. A method of producing an electrochemical nuclear fusion reaction comprising the steps of applying pulsed electrical energy to a solution containing heavy water to produce an electrochemical reaction for nuclear fusion reaction.

5. The method of Claim 4, wherein the pulsed electrical energy is applied with a duty ratio of 10% to 90% and at a rate of 1 to 1000 cycles per minute.

6. The method of Claim 5, wherein the electrochemical reaction is produced in a hermetically sealed space; and the high pressure is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction is carried out under the high pressure.

7. An electrochemical nuclear fusion reaction apparatus comprising a reaction vessel having a

pair of electrodes disposed therein and adapted to hold a solution containing heavy water therein, so that the pair of electrodes are immersed in the solution, a pulsed electrical energy device for applying electrical energy across the electrodes to produce an electrochemical reaction for a nuclear fusion reaction.

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8. The electrochemical nuclear fusion reaction apparatus of Claim 7 further comprising a means to produce a high pressure greater than atmospheric pressure in the reaction vessel.

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9. The electrochemical nuclear fusion reaction apparatus of Claim 8, wherein the reaction vessel is hermetically sealed, so that the high pressure in the reaction vessel is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction may be carried out under the high pressure.

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10. The electrochemical nuclear fusion reaction apparatus of Claim 8, wherein a shield plate means is provided to prevent the deuterium and oxygen from being mixed.

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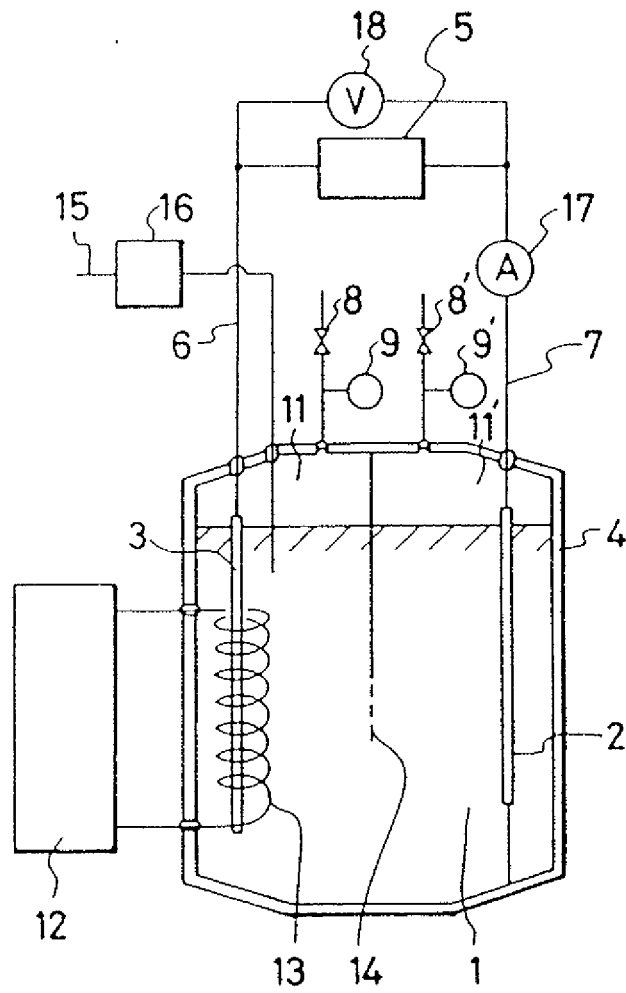
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FIG. 1



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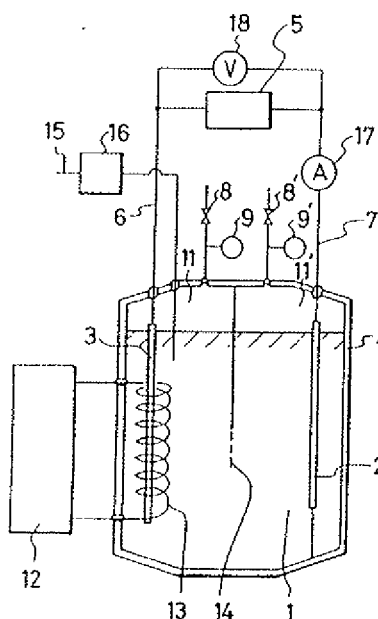
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FIG. 1



## ELECTROCHEMICAL NUCLEAR FUSION METHOD

BACKGROUND OF THE INVENTIONField of the Invention

The present invention relates to a method of attaining improved reliability in the implementation of a nuclear fusion reaction, and specifically to a method of controlling the extent of that nuclear fusion reaction by using a pulsed voltage for DC current.

Description of the Prior Art

A nuclear fusion reaction by electrochemical process, which is referred to as cold nuclear fusion, has been attained and reported by S.E. Jones et al. The paper is entitled "Observation of Cold Nuclear Fusion in Condensed Matter" and was authored by S.E. Jones, E.P. Palmer, J.B. Crirr, D.L. Decker, G.L. Jensen, J.M. Thorne, S.F. Taylor, (all of Brigham Young University), and J. Rafelski (University of Arizona).

In this reaction, a pair of electrodes comprising a palladium or titanium cathode and a gold or platinum anode are inserted into a solution containing heavy water, and a DC voltage is applied across these electrodes. In addition, the electrochemical nuclear fusion reaction is carried out at an atmospheric pressure.

Because of the fact that this reaction is carried out at the atmospheric pressure, there is little possibility that deuterium (D) atoms combine with other deuterium atoms to produce the nuclear fusion.

In addition, the reaction tends to occur in one localized section of the electrodes, and then the nuclear reaction would occur in that localized section from the rise in temperature at that point.

Also, palladium which is used as a catalyst for combining the deuterium atoms is easily poisoned to form a poisoned film, and it is difficult to break down the poisoned film to produce a uniform nuclear fusion. For this reason, there is a high degree of variation and a lack of reproducibility in the nuclear fusion reaction. In addition, because of the occurrence of electrochemical side reactions which takes place simultaneously with the nuclear fusion, most of the products of the reaction decompose and the deuterium is eventually released into the atmosphere. As a result, the amount of deuterium actually used in the nuclear fusion reaction is considerably less than expected. Therefore, a method of reliably controlling the nuclear fusion reaction with a high probability of nuclear fusion occurring is

further required.

SUMMARY OF THE INVENTION

An object of the present invention is to provide, with due consideration to the drawbacks of such conventional methods, a method by which it is possible to reliably implement an electrochemical nuclear fusion reaction by maintaining the reaction environment under high pressure.

A further object of the present invention is to provide a method by which it is possible to control the extent of the nuclear fusion reaction by applying a pulsed DC voltage to the reaction system and keeping the voltage enough high to produce the nuclear fusion reaction.

A further object of the present invention is to provide a method by which it is possible to control the extent of the nuclear fusion reaction by changing the pulse width or duty ratio of the pulsed voltage in the reaction system including a palladium electrode, so that the reaction is uniformly carried on over the palladium electrode.

A further object of the present invention is to provide an apparatus in which it is possible to reliably implement an electrochemical nuclear fusion reaction by applying a pulsed DC voltage to a solution for reaction in the apparatus and keeping the voltage enough high to produce the nuclear fusion reaction.

These objects are achieved in the present invention by the provision of a method wherein the reaction vessel containing a solution for reaction is maintained at a high pressure, and a pulsed DC current is applied to the solution to produce the electrochemical nuclear fusion reaction under control.

In the present invention, the high pressure in the reaction vessel can be produced for reaction by confining in the reaction vessel the deuterium (D<sub>2</sub>) per se produced as a gaseous material in the electrochemical reaction, so that the efficiency of the nuclear fusion reaction is totally increased.

In the present invention, the thermal energy produced in this reaction is transferred into a heat transfer medium which is passing through a heat exchanger in the reaction vessel. By conducting this heat transfer medium from the reaction vessel, it is possible to remove the energy, in particular the thermal energy from the nuclear fusion reaction for use as a simple thermal energy source in industrial applications such as electrical generation, heating, and the like.

### BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features, and advantages of the present invention will become more apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a device for experimental execution of the method of the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a reaction method and an apparatus by which it is possible to implement an electrochemical nuclear fusion reaction under control by applying a pulsed-type DC voltage.

The process in the present invention is carried out in a reaction vessel into which a pair of electrodes are incorporated. Specifically, for example, palladium or titanium is used for the cathode and gold or platinum for the anode of the electrodes in the present invention.

A pressurized reaction vessel is used for the reaction vessel to accommodate a solution which contains heavy water.

A DC voltage in the form of a continuous DC voltage or a pulsed-type DC voltage from a power source is applied between the electrodes.

A pair of heat exchangers are provided to remove the energy of nuclear fusion from the pressurized reaction vessel in order to prevent the excessive increase in temperature within the reaction vessel.

Further, a shield plate is inserted between the electrodes to prevent mixing of deuterium ( $D_2$ ) and oxygen ( $O_2$ ) which are produced through reaction, thus preventing the generation of heat from a further chemical reaction.

The deuterium and oxygen may be used to increase the pressure in the reaction vessel by making the reaction vessel in a hermetic structure.

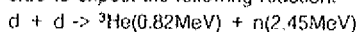
In the process of the present invention, a solution of heavy water ( $D_2O$ ) containing a predetermined metal salt is introduced between the electrodes in the reaction vessel. This metal salt is selected from the group of  $FeSO_4 \cdot 7H_2O$ ,  $NiCl_2 \cdot 6H_2O$ ,  $PdCl_2$ ,  $CaCO_3$ ,  $LiSO_4$ ,  $NaSO_4 \cdot 10H_2O$ ,  $CaH_4(PO_4)_2 \cdot H_2O$ ,  $TiSO_4 \cdot H_2SO_4 \cdot 8H_2O$ , and  $AuCN$ . Specifically, 0.03 to 0.3 gm of the salt, for example, 0.13 gm of the salt is added to 100 gm of the heavy water.

In addition,  $HNO_3$  is added to the solution to adjust the pH of the solution to 3 or lower.

An external voltage, specifically a pulsed DC

voltage, is applied across the electrodes, and atoms of deuterium ( $D$  or  $d$ ) are created at the palladium cathode while oxygen is produced at the anode. A neutron counter is positioned close to the reaction vessel to provide evidence to confirm the occurrence of nuclear fusion.

The neutrons ( $n$ ) are detected on the cathode side to expect the following reaction:



In addition to the reaction above, the following reaction can be expected to occur at the same time:



As a result of nuclear fusion, an increase in temperature of the heavy water solution is observed. The number of neutrons with an energy of 2.5 MeV is not necessarily large, but their existence can be detected with a neutron spectrometer.

When nuclear fusion takes place under pressure the neutrons cause the subsequent nuclear fusion by breeding, which may lead to an atomic explosion. Therefore, to prevent the occurrence of the atomic explosion, the extent of the electrochemical reaction must be controlled. For this reason, an adequately higher voltage than the voltage necessary for the reaction is applied, and the voltage is intermittently applied, in other words, the duration of application of the voltage is pulsed and controlled corresponding to the nuclear fusion reaction condition, whereby the reaction is controlled so as not to exceed the nuclear fusion critical value.

Specifically, the pulsed voltage is applied at 1 to 1000 pulses per minute and the pulse width is also varied from 0.1% to 100%. The 100% pulse width means a continuous state, which is referred to as DC continuous voltage. As a result, in the case where the DC continuous voltage is applied, the existence of nuclear fusion is observed even at as little as 20 V. In the case where a sufficiently high DC pulsed voltage, for example, 30 to 100 V, and especially, for example, at 40 V is applied with a duty ratio of 50% and a frequency of 30 times per minute, it is possible to suppress or control the extent of the nuclear fusion. Here, the term "duty ratio of 50%" means that the voltage is applied for 50% of a single cycle with no voltage applied for the other 50% of the cycle.

Furthermore, the extent of the creation of neutrons and the extent of the temperature rise is seen to increase as the pressure in the reaction vessel increases.

In comparison with the case where the reaction is carried out at atmospheric pressure, the nuclear fusion reaction is obviously accelerated when the reaction at the cathode is implemented under high pressure. The pressurization can be varied over the range from 2.3 atm to 200 atm provided that normal atmospheric pressure is equivalent to one atm.

The reaction can, of course, be implemented at greater pressures, but in such a case there is some danger of an explosion occurring, and it can be assumed that the danger increases with the increase in the efficiency of the reaction.

The present invention will become more clear by the following examples.

#### EXAMPLE 1

Now referring to FIG. 1, which illustrates the nuclear fusion reaction vessel used in the present invention, a pressurized reaction vessel 4 was used for the nuclear fusion reaction vessel, and a solution 1 which essentially consisted of heavy water ( $D_2$ ) and a salt added to the heavy water was enclosed in the pressurized reaction vessel 4.

A pair of electrodes 2, 3 fabricated of gold and palladium respectively were used in the reaction vessel 4. A DC voltage, e.g. of 40V in the form of a pulsed-type DC voltage from a power source 5 was applied between the palladium electrode 3 as the cathode and the gold electrode 2 as the anode with a duty ratio of 50%. Specifically, the voltage is applied for 50% of a single cycle with no voltage applied for the other 50% of the cycle.

A pair of heat exchangers 12, 13 were provided to remove the energy of nuclear fusion from the vessel 4 in order to prevent the increase in temperature within the reaction vessel 4 from proceeding too far. The heat exchanger 13, which was a spiral-type heat exchanger, was positioned adjacent to the palladium electrode (cathode) 3. A shield plate 14 fabricated from lithium glass was inserted between the electrodes 12, 13 to prevent mixing of deuterium ( $D_2$ ) 11 and oxygen ( $O_2$ ) 11' which were produced through reaction, thus preventing the generation of heat from a chemical reaction between the deuterium ( $D_2$ ) 11 and the oxygen ( $O_2$ ) 11'.

When the pressure has become too high, the oxygen 11' is let to go out of the reaction vessel 4.

The catalyst electrode or palladium electrode 3 is placed under a high pressure to absorb the deuterium ( $D_2$ ) gas contained in the heavy water.

The deuterium and oxygen were used to increase the pressure in the reaction vessel. In addition, a pair of safety valves 8, 8' and a pair of pressure gauges 9, 9' were provided for adjustment of the pressure. The DC power source 5 was connected to the electrodes 3, 2 respectively through a pair of leads 6, 7. The leads 6, 7 were electrically isolated from the reaction vessel 4.

In this example, the reaction vessel 4 produced for an experiment purpose was sized so that at most about 20 cc of reactants could be charged into the reaction vessel 4. However, if this nuclear

fusion reaction are to be used for industrial purposes, the size of the reaction vessel can be increased, so that a charge of 10 to  $10^4$  times this amount may be accommodated, or it would be possible to use a plurality of such small reaction vessels juxtaposed.

In addition, a supplementary supply of the solution 1 may be continuously charged into the reaction vessel 4 from an external source 15 of solution through a pressure charging system 16.

In this experiment example, 10 cc of heavy water ( $D_2O$ ) containing a salt were charged into the high pressure reaction vessel 4. The salt used was  $NiCl_2 \cdot 6H_2O$ , which was added in the ratio of 0.13 vol% of the heavy water. The pH of the solution was adjusted to 2.8 by the addition of nitric acid.

In the experiment, a continuous DC voltage was initially applied between the palladium electrode as the cathode and the gold electrode as the anode and deuterium ( $D_2$ ) was produced at the cathode and neutrons were detected by a neutron counter (omitted from the drawing). At this time, when the reaction was occurring at atmospheric pressure, a count of only about 4, in another words 3 to 10, was observed at an energy of 2.5 MeV, but, for example, when the duty ratio was increased to 75% in a manner that the voltage was applied for the time period of 45 seconds with no voltage for the 15 seconds in a single minute, the count number increased by about 6 times.

In addition, water was circulated through the heat exchangers 12, 13, and heat generation in this circulated water was clearly observed.

The deuterium 11 and oxygen 11' generated from this nuclear fusion reaction with the pulsed voltage application were not released to atmosphere but were confined within the high-pressure reaction vessel 4 to increase the pressure therein. A predetermined pressure can desirably be maintained by ejecting through the safety valves any gaseous materials which were not required. In this example, oxygen gas was ejected as unnecessary gaseous material. This release of oxygen was also made to prevent a secondary electrochemical heat generation reaction between deuterium and oxygen in the pressurized state to prevent a sudden generation of heat.

It was found in Example 1 that deuterium adhered to the cathode of palladium electrode 3 during the reaction when the voltage applied at the power source 5 was increased 50V as detected at the voltmeter 18. However, when the deuterium was adhering to the palladium electrode 3, the result was a trend toward diminishment of the area of the palladium electrode 3. This was observed experimentally. Therefore, the reaction could not be kept uniform over the total electrode area. Because of this, the breeding by neutrons generated

from parts of the reaction concentrated in localized areas caused more positive nuclear fusion reaction in the areas.

It was also found in Example 1 that when the reaction was carried on for one hour, surface poisoning occurred in the palladium electrode 3 and thereafter an adequate nuclear fusion reaction could not be produced at the same voltage.

In this example, it was also found important to remove any catalyst poison to prevent the catalytic reaction on the palladium side.

## EXAMPLE 2

The embodiment in Example 2 was carried out in the same manner as Example 1, except that the voltage applied at the power source 5 was increased to 60 V as detected at the voltmeter 18. This caused the electric current through the line 7 to increase as detected at the ammeter 17.

In addition, taking into consideration of the localized reaction as mentioned above in Example 1 when the voltage was applied high, an alternative experimental procedure was adopted, that is, a voltage sufficient to produce the nuclear fusion reaction was applied, and a pulse width duty ratio of 100% (DC voltage) was not used, but rather the duty ratio was varied in a range less than 100%, so that a nuclear fusion reaction occurred intermittently. The term "pulse width duty ratio" means the period of time in ratio through which voltage is applied during one cycle.

Therefore, the reaction was produced uniformly over the entire cathode of palladium electrode 3 and it was also possible to control the extent of the nuclear fusion reaction, inasmuch as the breeding was not caused by subsequent neutrons. Therefore it was expected that the generation of nuclear fusion could desirably be controlled. Specifically, in Example 2, a DC voltage of 60 V was applied and the duty ratio was varied from 10% to 90%. For example, a 50% duty ratio was attained wherein 50 V was applied between the two electrodes during 50% of the time period over one minute.

By varying the duty ratio from 10% to 90% to intermittently apply a higher voltage, the number of neutrons was also increased in proportion. Consequently, in Example 2, it was possible even after 10 hours to obtain a satisfactory nuclear fusion reaction at the same voltage as initially applied, and the temperature in the circulated water correspondingly rose from room temperature to 40°C. It was recognized that the palladium electrode was prevented from being poisoned, and any poisoned film was substantially not produced.

By means of the present invention, it has become possible to continuously carry on an artificial

nuclear fusion reaction, controlling the extent of the reaction, which had been deemed impossible to perform in the past. For this reason, the present invention has extremely large industrial implications.

The efficiency of the heat exchangers to remove energy from the reaction vessel can further be increased, so that removal as boiling water at 100°C to 130°C is possible by improving and making scale-up the nuclear fusion reaction device. These are also modifications of the present invention.

In addition, other modifications are possible within the scope of the present invention.

## Claims

1. A method of producing an electrochemical nuclear fusion reaction comprising the steps of: providing a reaction vessel,

providing the reaction vessel with a pair of electrodes disposed therein,

introducing in the reaction vessel a solution containing heavy water, so that the pair of electrodes are immersed in the solution; and

applying pulsed electrical energy across the electrodes to produce an electrochemical reaction for a nuclear fusion reaction.

2. The method of claim 1, wherein the pulsed electrical energy is applied with a duty ratio of 10% to 90% and at a rate of 1 to 1000 cycles per minute.

3. The method of Claim 2, wherein the electrochemical reaction is produced in a hermetically sealed space; and the high pressure is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction is carried out under the high pressure.

4. A method of producing an electrochemical nuclear fusion reaction comprising the steps of applying pulsed electrical energy to a solution containing heavy water to produce an electrochemical reaction for nuclear fusion reaction.

5. The method of Claim 4, wherein the pulsed electrical energy is applied with a duty ratio of 10% to 90% and at a rate of 1 to 1000 cycles per minute.

6. The method of Claim 5, wherein the electrochemical reaction is produced in a hermetically sealed space; and the high pressure is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction is carried out under the high pressure.

7. An electrochemical nuclear fusion reaction apparatus comprising a reaction vessel having a

pair of electrodes disposed therein and adapted to hold a solution containing heavy water therein, so that the pair of electrodes are immersed in the solution, a pulsed electrical energy device for applying electrical energy across the electrodes to produce an electrochemical reaction for a nuclear fusion reaction. 5

8. The electrochemical nuclear fusion reaction apparatus of Claim 7 further comprising a means to produce a high pressure greater than atmospheric pressure in the reaction vessel. 10

9. The electrochemical nuclear fusion reaction apparatus of Claim 8, wherein the reaction vessel is hermetically sealed, so that the high pressure in the reaction vessel is produced by confining deuterium and oxygen, which are the products of the electrochemical reaction, whereby the nuclear fusion reaction may be carried out under the high pressure. 15

10. The electrochemical nuclear fusion reaction apparatus of Claim 8, wherein a shield plate means is provided to prevent the deuterium and oxygen from being mixed. 20

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FIG. 1

